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Viewpoint

Monitor social–ecological systems to achieve global goals for biodiversity and nature's contributions to people

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The adoption of the Kunming–Montreal Global Biodiversity Framework (GBF) has opened a critical window of opportunity for ecosystem conservation and restoration to respond to the biodiversity and climate crises. The GBF has sparked worldwide interest in biodiversity monitoring to track outcomes and to guide action from local to global scales (Gonzalez and Londoño 2022). However, the GBF separates monitoring the progress toward outcomes for biodiversity in the targets of Goal A from monitoring outcomes for nature's contributions to people in the targets of Goal B. Separate monitoring for these two goals is a problem, because the biodiversity and ecosystem services outcomes that are the joint focus of the GBF arise from people–nature interactions in complex social–ecological systems. Isolated monitoring for these two goals perpetuates the disconnections between biodiversity conservation and human well-being (Mace 2014, Isbell et al. 2017), whereas conservation that integrates people and nature has repeatedly proven to be more successful (Reyes-García et al. 2019). Making smart decisions about maintaining the benefits we obtain from nature into the future depends on a clear and accurate understanding of these complex systems, which can be obtained through the establishment of integrated ecosystem service observation networks (ESONs) that weave together the data and information needed to assess outcomes for the GBF's targets for biodiversity, ecosystems, and human well-being.

Challenges in ecosystem service monitoring

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) framework (Díaz et al. 2015) highlighted the links among biodiversity, ecosystems, and people in social–ecological systems and established a conceptual framework including all of these factors. Although some components of this framework are consistently addressed in monitoring (including biodiversity, provisioning ecosystem services, some aspects of human health and economic well-being, and many anthropogenic drivers of change), others are much less frequently considered or entirely omitted (such as most regulating and cultural ecosystem services and especially the links between various components; figure 1).

Despite its ambition to be a whole-society approach, the GBF does not systematically consider the interconnections among components. Indicators for GBF targets and goals address only very few aspects of social–ecological systems. For example, for targeting the sustainable use of wild species, no other group than fish is considered as an indicator, with a focus on stock sizes, but there is no consideration for population dynamics, catch effort, or the local communities' benefits obtained from fishing. The GBF approach focuses on the *use* of ecosystem services without reflecting on whether people's needs are met or whether use happens in a sustainable way. Without monitoring whole systems, we do not have the information needed to mitigate and manage pressures and drivers (see the example in supplemental figure S1), nor any of the ecosystem functions endangered by unsustainable or exploitative use (Falardeau and Bennett 2020, Bennett and Reyers 2024). In the present article, we describe three challenges for monitoring social–ecological systems and the gaps they come from and suggest a way forward.

Challenge 1

Monitoring for nature conservation is mostly centered on biodiversity, with little attention to how changes in biodiversity affect ecosystem services and people's well-being. Although there is agreement on the importance of links between biodiversity and ecosystem services, the way these links work is often not straightforward, they are hard to detect, or they involve time lags between the drivers and the outcomes that lead to an ecosystem services debt (Harrison et al. 2014, Isbell et al. 2015, 2017). Biodiversity also has a more general effect on ecosystem stability and resilience, serving as insurance for balancing out and recovering from unexpected events (Loreau et al. 2003, Folke et al. 2004). Furthermore, linking the observed changes in biodiversity and ecosystem services to drivers and pressures (causal attribution) requires the understanding of causal networks that relate change in variables to outcomes for people and nature (Gonzalez et al. 2023a, Mori et al. 2023). This is challenging because we often lack data linking drivers to biodiversity and ecosystem variables at the right scales, and both data and models come with considerable uncertainties (Gonzalez et al. 2023b).

Challenge 2

Systematically designed monitoring variables for ecosystem services, such as the essential ecosystem services variables (EESV), are much less developed than those for biodiversity (Balvanera

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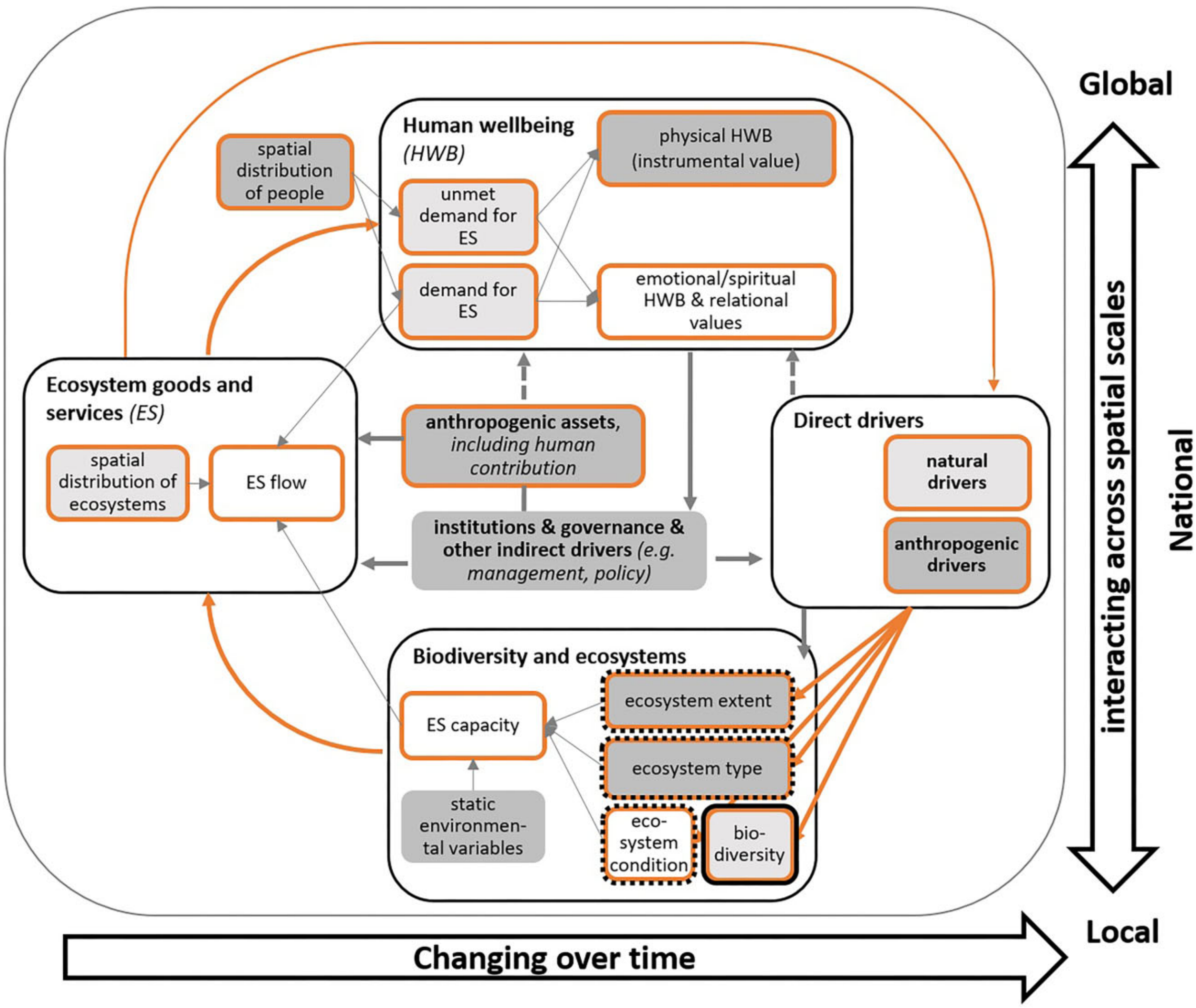

Figure 1. Components of an Ecosystem Service Observatory Network (ESON) mapped onto the IPBES conceptual framework (based on Diaz et al. 2015). Components that would be monitored in ESONs are with thick outlines. Biodiversity Observation Network (BON) focus is outlined in black and black dashed for further components targeted. Where the original IPBES conceptual framework has six primary components (bold text), we have further broken some of these down into their component parts for more precision. These shades represent the amount of data potentially available, with darker shades of grey indicating greater data availability.

et al. 2022, Schwantes et al. 2024). The essential ecosystem services variables framework, with its six classes of essential variables, each capturing key aspects of ecosystem services coproduction, provides a structure for assessing ecosystem services that needs to be developed further (Balvanera et al. 2022). However, indicators for ecosystem services are nevertheless challenging to define, because they must encompass multiple aspects (e.g., demand for ecosystem services, use of ecosystem services, capacity of the ecosystem to supply ecosystem services; Haines-Young and Potschin 2010), which requires a combination of models and disparate data sources, as well as different types of disciplinary knowledge (Firkowski et al. 2021, Schwantes et al. 2024).

Challenge 3

Interactions in social–ecological systems are scale dependent but assessments often target a single spatial level—for example, the national Mapping and Assessments of Ecosystem Services, in Europe, or national biodiversity strategies and action plans (NBASPs). The inclusion of social–ecological perspectives requires a multiscale approach, because the benefits of nature do not stay in one place and can move (Schröter et al. 2018) or be moved (Liu et al. 2013). Scale is a cross-cutting challenge that underpins questions of generalizability and transferability of knowledge across different geographical and administrative levels (Bennett et al. 2021). Therefore, there is no one monitoring blueprint that works for all, and place-based approaches are indispensable. Monitoring must be designed to assess how ecosystem services at different scales change and interact with other components of the social–ecological system.

The complexity of social–ecological systems has been an important and challenging topic for decades (e.g., Millennium Ecosystem Assessment 2003, Bourgeron et al. 2023). Assessments that address this challenge have been implemented in a variety of contexts (e.g., in the European Union, Maes et al. 2020, or in Canada, Bennett et al. 2021). However, a unified global approach that accounts for complex social–ecological systems has not yet been developed.

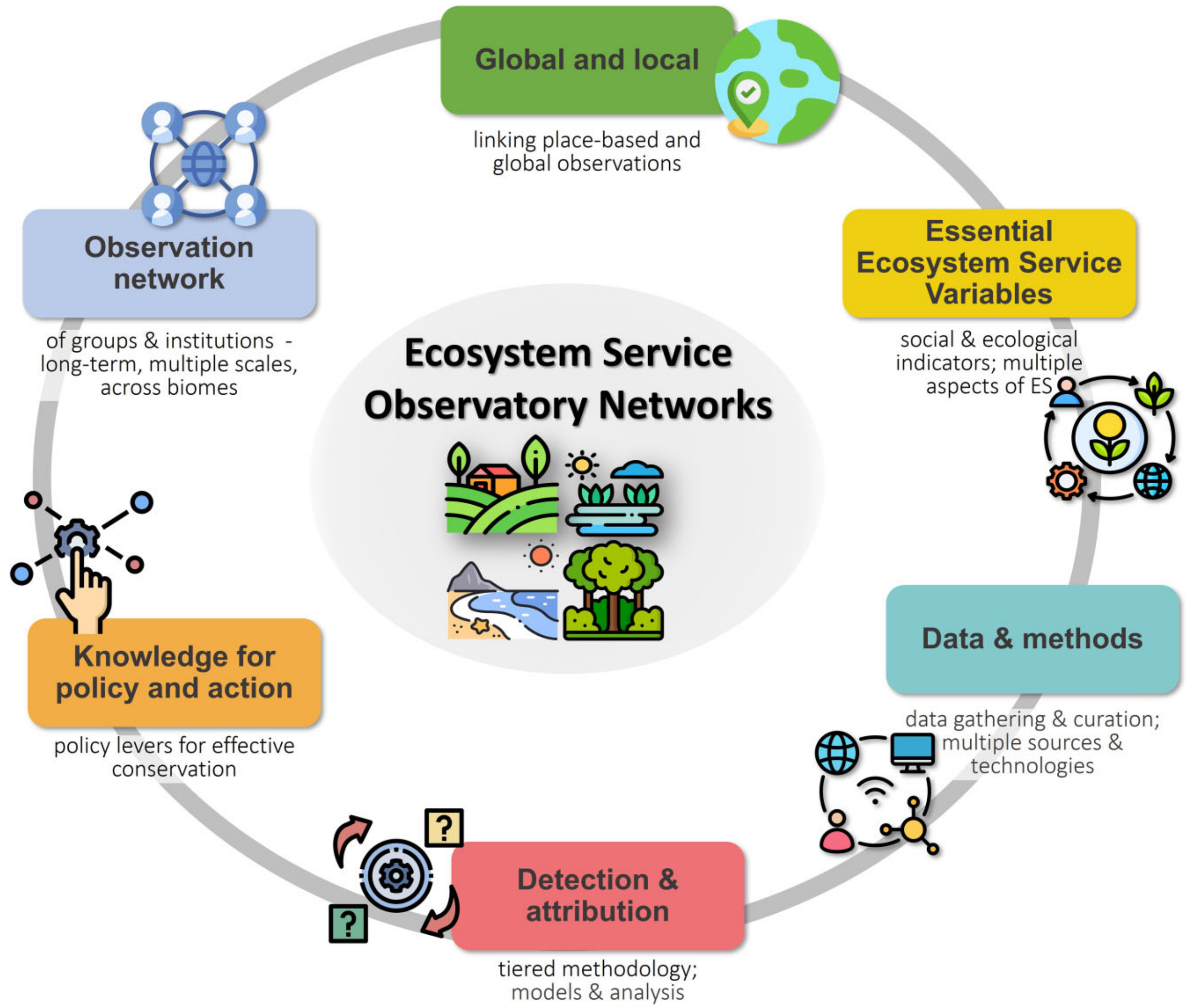

Figure 2. Features of the suggested ESON.

Ecosystem services observation networks to fill the gaps

To address the gaps listed above, we call for the establishment of ecosystem services observation networks (figure 2) to be integrated seamlessly into the ongoing implementation of national and regional biodiversity observation networks (Navarro et al. 2017). Because social–ecological systems are complex, monitoring must be designed in a way that takes all their features into account. An ecosystem services observation network is a network of observation sites and groups at different geographical and administrative scales organized to carry out long-term integrated monitoring of social and ecological variables at multiple scales, addressing all three of the challenges that currently vex ecosystem services monitoring (Firkowski et al. 2021). Integrating ESONs with BONs will allow countries to jointly and holistically monitor ecosystem services and biodiversity to support the detection of change and of causal links (Gonzalez et al. 2023b).

Linked ESONs and BONs meet the challenges of monitoring by enhancing the focus on monitoring ecosystem services and their links to biodiversity and people, bringing together knowledge (challenge 1). To do this, the use of a structured monitoring framework, as was suggested with the essential ecosystem services variables, is essential (challenge 2). This structured and holistic monitoring is the basis for causal analysis, for the identification of drivers, and for fine-tuning management while taking into account people's needs. With linked ESONs and BONs, we can combine multiple types and scales of data—for example, remote sensing, national census data, field sampling, community-based monitoring, and traditional ecological knowledge enabling the analysis of large-scale patterns with the capacity to zoom in to place-based processes with the engagement of local communities (challenge 3).

Work to implement several science-policy frameworks that require updated estimates of ecosystem services status and trends can spur the development of methods for monitoring ecosystem services (Schwantes et al. 2024). At the global scale, the United Nations' *System of Environmental–Economic Accounting: Ecosystem Accounting* (SEEA-EA) provides the best developed methods and theoretical backing (United Nations 2021), its application in *ARIES for SEEA* is a useful foundation (United Nations 2022), whereas in

Europe, work on the European Union's Mapping and Assessment of Ecosystem Services has advanced and streamlined methods (Vári et al. 2024). Drawing on these experiences in a modular and multitiered way enables ESONs to combine global and local approaches.

Galvanizing action

We call on the scientific community to develop a framework for jointly monitoring biodiversity and ecosystem services, and, critically, to focus on their interlinkages to guide appropriate monitoring practices and technologies for the actions and outcomes sought by the GBF. This should work with the recently launched IPBES methodological assessment on monitoring biodiversity and nature's contributions to people and should contribute knowledge to the United Nations' Convention on Biological Diversity's Conference of the Parties and the supporting scientific and technical bodies. For implementation, collective action is needed: Both civil and government organizations that have the capacity to establish and run ESONs will be essential for linking regional, national, and international monitoring. ESONs will enable us to measure progress toward international goals and targets and to deliver key information needed to guide conservation worldwide.

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Supplemental data

Supplemental data are available at *BIOSCI* online.

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